9-2022

Project-Based Learning Promotes Students'Perceived Relevance in an Engineering Statistics Course: A Comparison of Learning in Synchronous and Online Learning Environments

Wen Huang

Jeremi S. London

Loga A. Perry

JOURNAL OF STATISTICS AND DATA SCIENCE EDUCATION
2022, VOL. 00, NO. 0, 1–9
https://doi.org/10.1080/26939169.2022.2128119

Taylor & Francis
Taylor & Francis Group

OPEN ACCESS Check for updates

Project-Based Learning Promotes Students' Perceived Relevance in an Engineering Statistics Course: A Comparison of Learning in Synchronous and Online Learning Environments

Wen Huang[a], Jeremi S. London[b], and Logan A. Perry[c]

[a]Department of Teaching and Learning, Simmons School of Education and Human Development, Southern Methodist University, Dallas, TX; [b]Department of Engineering Education, Virginia Polytechnic Institute and State University, Blacksburg, VA; [c]Department of Civil and Environmental Engineering, University of Nebraska-Lincoln, Lincoln, NE

ABSTRACT

Understanding statistics is essential for engineers. However, statistics courses remain challenging for many students, as they find them rigid, abstract, and demanding. Prior research has indicated that using project-based learning (PjBL) to demonstrate the relevance of statistics to students can have a significant effect on learning in these courses. Consequently, this study sought to explore the impact of a PjBL intervention on student perceptions of the relevance of engineering and statistics. The purpose of the intervention was to help students understand the connection between statistics and their academic majors, lives, and future careers. Four mini-projects connecting statistics to students' experiences and future careers were designed and implemented during a 16-week course and students' perceptions were compared to those of students who took a traditional statistics course. Students enrolled in the experimental group (a synchronous learning experience) and the control group (an online learning experience) were sent the same survey at the end of the semester. The survey results suggest that the PjBL intervention could potentially increase students' understanding of the usefulness of statistics and effectively enhance their perceptions of belonging to the engineering community. This study summarizes the results of this PjBL intervention, the limitations of the research design, and suggests implications for improving future statistics courses in the context of engineering.

ARTICLE HISTORY
Received July 2021
Accepted September 2022

KEYWORDS
Active learning; Engineering education; Experiential learning; Introductory statistics; Statistics education

1. Introduction

Statistical literacy is essential for engineers. A critical component of the scientific method, statistics are used by engineers for model verification, product design, and operation improvement (Montgomery, Runger, and Hubele 2010). Engineering students are typically required to take at least one entry-level statistics course in the first two years of their program. However, university statistics courses have long been criticized for being overly rigid, abstract, and unenjoyable for learners (Neumann, Hood, and Neumann 2013). Students often report negative attitudes and feelings of anxiety when taking a statistics course or conducting statistical analyses (Rivera, Marazzi, and Torres-Saavedra 2019; Wathen and Rhew 2019), and many students perform poorly in statistics courses (Wathen and Rhew 2019). As a result, statistics instructors face a steep challenge in trying to motivate students and help them to develop positive associations with statistical knowledge (Songsore and White 2018).

1.1. Project-Based Learning (PjBL)

Many researchers and instructors have used project-based learning (PjBL) to solve the instructional challenges of statistics courses (Larsen et al. 2018; Neumann, Hood, and Neumann 2013; Tawfik and Lilly 2015; Wathen and Rhew 2019). PjBL is a student-centered instructional method that supports learners by actively engaging them in context-specific tasks and enabling them to achieve final products (e.g., design and presentation) through collaboration and knowledge sharing (Kokotsaki, Menzies, and Wiggins 2016; Prince and Felder 2006). This method is rooted in the constructivist theories of learning and emphasizes learners' use of their prior experience and understanding to generate new knowledge through a sense-making process (Du and Han 2016; Ravitz 2010).

Theoretical differences exist between PjBL and problem-based learning. PjBL is a product-oriented approach that starts with narrowly formulated tasks, whereas problem-based learning usually begins with an open-ended, ill-structured, real-world problem and focuses on the process of problem manage-

CONTACT Wen Huang buaakoben@gmail.com Department of Teaching and Learning, Simmons School of Education and Human Development, Southern Methodist University, Dallas, TX 75205.

Supplementary materials for this article are available online. Please go to www.tandfonline.com/ujse.

ment (Kokotsaki, Menzies, and Wiggins 2016; Prince and Felder 2006; Savin-Baden 2007). However, the distinction between these two approaches is often negligible in practice, and many PjBL programs also include open-ended, ill-structured, real-world problems (Kolmos and de Graaff 2014; Martonosi and Williams 2016; Prince and Felder 2006).

1.2. PjBL in Engineering Statistics Classes

Several studies have focused on the introduction of project-based interventions within entry-level engineering statistics courses. In a typical intervention design, students solve open or semi-open questions by interpreting real-world data they collect in small groups. Although the data sources vary, the data themselves often relate to students' majors, interests, or lives. Larsen et al. (2018) describe their approach to helping students understand the concepts of probability and related statistical analytical methods in a second-year engineering statistics class. Their curriculum was lab-based, and students were required to analyze the data generated by throwing darts or rolling marbles repeatedly. Farrell and Carr (2019) designed a second-year statistics course for engineering students, in which students worked in small groups to solve short, authentic, projects after traditional classroom lectures on each topic. Farrell and Carr's projects were drawn from topics related to the students' lives and were not limited to the engineering field. Andersson and Kroisandt (2021) required students in their online industrial engineering statistics course to complete a small practical task in small groups each week that related to the main topic covered in the previous week. In addition, they gave student groups a list of comprehensive statistical projects. Each group chose one of the projects and worked with this project throughout the semester. Erdil (2021) describes a project for fostering entrepreneurial mindsets that was implemented in a junior-level engineering statistics course. In this project, bags of milk chocolate candies were used in an in-class activity to help students learn the fundamentals of descriptive statistics, and discuss product quality and deviation.

1.3. PjBL Outcomes in Statistics Learning

The outcomes of PjBL in statistics courses have been positive overall. Students have demonstrated a high interest in engaging in learning activities that involve real-life questions and data (Cetinkaya-Rundel et al. 2022; Larsen et al. 2018; Neumann, Hood, and Neumann 2013; Wathen and Rhew 2019), and the relevance of these questions and data has encouraged students' further interest in statistics (Neumann, Hood, and Neumann 2013; Tawfik and Lilly 2015). Students have reported appreciating the integration of projects into statistics courses and believing this method was effective (Delucchi 2007; Vidic 2011; Wathen and Rhew 2019). They have also reported that exploring real-world questions and/or using real-life data helped them remember concepts and understand the practical applications of statistics (Farrell and Carr 2019; Neumann, Hood, and Neumann 2013). They recognized the importance of planning and organization in project management and the skills to present statistical results in the context of the original research question (Halvorsen 2010). Students agreed that engaging in real-world tasks in small groups increased their collaboration and data analysis abilities (Farrell and Carr 2019).

Students' learning achievements after PjBL interventions are also encouraging. Students who completed application exercises designed to mimic real-world contexts reported more real-world use of statistics after the exercises than control students (Daniel and Braasch 2013). Students in the experimental group also obtained higher scores in questions that tested learning transfer. In Erdil's (2021) research, the project-based intervention was determined to have successfully fostered students' entrepreneurial mindsets, because more than 70% of the class obtained higher scores than expected.

A possible explanation for the favorable PjBL outcomes in students' statistics learning is that linking learning objectives to students' interests, lives, and real-world questions can increase students' perceptions of the material's relevance (Priniski, Hecht, and Harackiewicz 2018). This changed perspective may further motivate students to apply energy to learning statistics. However, few studies have explored students' perceptions of statistics relevance after a PjBL intervention. Spence, Bailey, and Sharp (2017) claimed that the PjBL intervention they developed did not lead to students' perceived usefulness of statistics being significantly higher in the experimental classes than in the control classes. One of the issues in their article was the absence of introducing and showing the instrument they used to measure the perceived usefulness of statistics; we do not know whether the instrument is valid and what it actually assesses. Thus, additional study in this area may help researchers and educators better understand the potential of PjBL in statistics course instruction.

1.4. Purpose and Guiding Question

The purpose of this study is to measure students' perceptions of statistics relevance after a PjBL intervention in an introductory engineering statistics course that explored the relevance of statistics. Thus, the question guiding this work is "What is the impact of a PjBL intervention on students' perceptions of statistics relevance in an engineering statistics course?"

2. Theoretical Framework

Priniski, Hecht, and Harackiewicz (2018) relevance research framework was employed to define the critical concepts of this study. According to this framework, relevance is defined as having "a personally meaningful connection to the individual" (p. 12). Relevance can stem from personal association, personal usefulness, and/or identification. Personal association is a perceived connection between the current stimulus and one's personal interest, focus, or memory. Personal usefulness means the individual perceived the utility value of the current stimulus to fulfill a personal goal. Identification implies that the stimulus is regarded as a part of the individual's identity. Each type of relevance represents an increase in personal meaningfulness and inclusiveness from the prior types. This study focuses on personal usefulness and identification. In this framework, personal identification is a concept similar to a sense of belonging but narrower than professional identity in general. Professional identity includes individuals' perceptions of themselves, evaluation of their capabilities in the field, and others' attitudes toward them (Morelock 2017; Tonso 2014).

3. Instructional Context and Research Methods

To address the research question, a PjBL intervention was conducted for one semester in a three-credit second-year engineering statistics course at a large public university in the southwest United States. The purpose of the PjBL intervention was to help students understand the connection between statistics and their academic majors, lives, and future careers. Four mini-projects connecting statistics to students' experiences and future careers were designed and implemented during the 16-week course. A semi-structured survey was conducted at the end of the semester, and students' responses were analyzed for markers of personal usefulness and personal identification.

3.1. Context and Participants

This study was approved by the Institutional Review Board at the institution in which it was conducted. The study included two parallel classes: the control class and the experimental class. The second author instructed the experimental class and a faculty member with a similar professional background instructed the control class. The two classes applied the same content, used the same textbook, and applied the same learning assessment criteria developed by the school. The core content included hypothesis testing, t-tests, regression, ANOVA, factorial experimental design, and statistical tool selection. The course instruction took place three days per week in one-hour class sessions. The control class was instructed online in a traditional lecture format, whereas the experimental class was instructed in a physical classroom. The four mini-projects were only used in the experimental class and were integrated into the course instruction (see Appendix A. Engineering Statistics Course Schedule, supplementary materials). Students' scores were graded based on a competency-based assessment, in which students should demonstrate their competencies in projects (experimental class only), homework, and/or exams (see Appendix B. Competency-Based Assessment, supplementary materials). Students in the control class were not required to do extra writing; they only needed to complete their homework assignment and exams, but no projects.

As a prerequisite for the engineering statistics course, students were required to have passed calculus or an analytic geometry course with a grade of at least C or better. A total of 110 students in on-campus engineering programs (e.g., software engineering, mechanical engineering, and electrical engineering) enrolled in the course (see Table 1). The class selection was based on student preference and the reasons for class selection were unknown to the faculty. The control class and the experimental class had 56 and 54 students, respectively. Before enrollment, these students only knew the faculty member's name and the instructional format (i.e., online or in-person). They did not know that the experimental class included extra mini-projects. In the first week, faculty members introduced the course syllabus, and students were allowed to switch between the two classes.

Table 1. Demographic information.

		Control class	Experimental class
Gender	Male	50	46
	Female	6	8
Academic level	First-year	0	1
	Second-year	16	18
	Junior	22	24
	Senior	18	10
	Post-Bacc undergraduate	0	1

3.2. Intervention

The experimental group was enrolled in an introductory statistics course that not only included some of the typical statistics homework sets and exams, it also included four mini-projects that were sprinkled throughout the semester. For example, in the second week, we had a project named "admissions essay rewriting." Specifically, this task situated participants in an imagined scenario. Two prospective students were interested in applying to the engineering program in which participants were enrolled. Participants were required to help these two applicants and use their situation as an example to write a compelling admissions essay that linked their background to their major and their career aspirations in less than 600 words. After completing their essays, they could exchange a copy of their revised letter with a peer in the course and provide feedback on the contents of the draft. Although not explicitly related to statistics, this mini-project's goal was to get students comfortable with asking the question *why*, which is at the heart of questions about relevance.

The second project was a video presentation of "a day in the life." This project was conducted in Week 5 when participants were learning descriptive data analysis. In teams of 2–3 people who were pursuing the same (or a closely related) engineering degree, participants produced a short (3–5 minute) YouTube video presentation. The presentations were to include the following descriptions: (a) key characteristics of the engineering discipline that distinguished it from other fields, (b) the participants' perspectives on "a day in the life" of an engineer in their desired profession, and (c) at least 2–3 examples of the kind of data that was useful to getting work done in the participants' desired engineering profession.

The third project was an experimental design. This project was conducted in Weeks 12–13 after participants had learned ANOVA, design of experiments, and JMP (SAS 2021) for statistical analysis. Participants were required to design an experiment around paper airplanes, miniature catapults, or chewing gum. They also needed to collect data, analyze the data, and make recommendations about which settings they felt were best in light of some measure of interest (e.g., distance, time). They would use two of the most advanced topics they had learned from the course: design of experiments and regression analysis.

The fourth project was a presentation of "a world with(out) statistics." Participants were grouped into teams of 4–5 people and required to creatively express the importance of statistics to their selected topic and/or what our world would be like if their topic did not have ties to statistics. The topics were related to participants' majors and interests (e.g., product development, robotics, healthcare, sports and entertainment). The site of their presentation was the school's innovation showcase at the end of the semester.

3.3. Data Collection

No participants switched between the experimental and control classes during the semester. Participants were not notified about this study until they were invited to complete an anonymous survey in the final week of the semester. Aside from demographic information, this survey included seven questions. Students' responses to two of these questions are analyzed in this article. The main body of our analysis is based on responses to the question "Provide at least three examples of how statistics is relevant to your engineering discipline, your anticipated career, and/or engineers, in general." In addition, participants' responses to the other question are reported ("On average, how many HOURS per week did you commit to preparing for and participating in this course?") in the conclusion and future work section. The aim of this analysis is to identify the effectiveness of the PjBL intervention in the engineering statistics course and suggest possible directions for future improvement of the intervention.

3.4. Analytical Approach

To understand the possible differences in students' perceptions of statistics relevance, we analyzed students' survey responses based on personal usefulness and personal identification. The initial analysis was conducted solely by the first author to identify patterns within the data. Emergent codes were discussed and reviewed by the remaining authors throughout the coding process but did not warrant testing of inter-rater reliability. Perceptions of relevance based on personal usefulness were identified through a content analysis that highlighted the differences between the control and experimental groups.

The directed coding method was employed in the content-coding process (Helgevold and Moen 2015). This method advocates using existing theory and research findings to develop the category system. The coding strategy began with the immediate application of predetermined codes, and improvements to this strategy were made throughout the coding process. A two-level initial coding framework was developed for this study. The first-level codes (i.e., categories) specified the nature of the content: data field, engineering field, no engineering field, or a non-relevant example (see Table 2). The second-level codes (i.e., themes) were exclusively applied to examples in the engineering field. The initial ten themes were drawn from the engineering practices identified by Trevelyan (2007) and necessary improvements were implemented during the coding process. Ultimately, five themes ("measurement"; "coordination, working with other people"; "engineering processes, project and operation management"; "business development or marketing, selling products or services"; and "technical work") emerged, and these themes were used to frame the further comparative analysis between the control class and the experimental class.

Table 2. Definition and example for each field.

Category	Definition	Example
Data	Limited to the data itself or data processing.	Taking data and using it for charts or graphs correctly.
Engineering	Relevant to students' engineering discipline or their future career.	Gathering data on electrical components or systems to optimize.
No engineering	Related to statistics but not related to engineering or data.	Probability of events happening in a game.
Non relevant	Not related to statistics.	When asked to compute something for a team, it will always be convenient to know how to do so when asked.

Perceptions of relevance on personal identification were analyzed with a linguistic approach. Personal pronouns may imply respondents' self-reflection on the stated events and an assumptive interactive relationship with readers of the narrative (Cohen 2014; Wales 1996). The use of first-person pronouns in participants' responses might reveal their personal perceptions about statistics, engineering, and themselves. Thus, first-person pronouns were regarded as an indicator of perceptions of relevance through personal identification.

We first compared the experimental and control groups' frequency of use of first-person pronouns. Next, we analyzed the discourse functions of the first-person pronouns in participants' responses. For this analysis, discourse function is defined as the function of a personal pronoun in the context of the sentence in which it is located. This function reflects the respondent's specific communicative purpose. Our comparative analysis of personal identification was based on the three discourse functions of first-person pronouns identified in the data (see Table 3).

4. Results

Eighty-three students ($n = 34$ in the control group and $n = 49$ in the experimental group) responded to the online survey. Responses in the control group and experimental groups included 83 and 159 (content) items, respectively.

4.1. Personal Usefulness Level

4.1.1. Content Category

Table 4 includes the number of items in each content category and theme. According to the survey question ("Provide at least three examples of how statistics is relevant to your engineering discipline, your anticipated career, and/or engineers, in general"), only content related to data or engineering was considered effective and included in the analysis. A higher proportion of response items in the experimental group were related to the engineering field than in the control group. In addition, each individual in the experimental group provided more effective items than individuals in the control group.

4.1.2. Comparison Between Groups

Only items related to the engineering field were used in this analysis. No meaningful differences in content were found between the experimental and control groups regarding the

Table 3. Discourse functions of first-person pronouns in participants' survey responses.

	Discourse function	Example
1.	State statistics-related skills that the respondent or the community has.	"I can use JMP for graphing and showing relationships in data in my future career."*
2.	Claim benefits of statistics for the respondent or the community in helping to complete a task.	"It helps me to know how to clear up data by tools."
3.	Establish links between statistics and respondents' projects, disciplines, or future careers.	a. "Statistics is relevant to my major in deciding where efforts need to be placed and what areas need to be focused on." b. "The chance that all my eggs will hatch in an incubator."

Notes: *JMP is a statistical software program tool introduced in Week 6 lectures, after instruction on descriptive statistics in Week 5 and prior to inferential statistics instruction in Week 7.

Table 4. The number of items in each content category.

	Number of items*	
Category	Control (%)	Experimental (%)
Data	19 (22.8)	10 (6.3)
Engineering	56 (64.5)	146 (91.8)
Measurement	5 (6.0)	10 (6.3)
Coordination, working with other people	4 (4.8)	2 (1.3)
Engineering processes, projects, and operation management	8 (9.6)	10 (6.3)
Business development or marketing, selling products or services	2 (2.4)	13 (8.2)
Technical work	36 (43.4)	107 (67.3)
No engineering	6 (7.2)	3 (1.9)
Non relevant	2 (2.4)	0 (0.0)
Total effective items**	75	156
Effective items per response	2.2	3.2

Note: *The number of (content) items students responded to the survey question. **The number of items whose content was related to data or engineering.

theme "measurement and coordination, working with other people," likely due in part to the small number of items. However, three meaningful differences were found for each of the remaining themes.

First, the two groups had almost the same number of items related to the theme "engineering processes, project, and operation management." However, the experimental group items included richer content than those of the control group. Control group content mainly focused on

1. the capabilities of statistics to predict, control, and review (quality and performance) and
2. the use of statistics by a process or project manager to measure team performance and the progress of a task.

Content from the experimental group included the following three aspects:

1. the use of statistics to predict the time and the cost of a project based on past projects,
2. the use of statistics to improve, track, predict, and measure a process, and
3. the use of statistics to measure the effect of a process on the system efficiency.

Second, only two items in the control group related to the theme "business development or marketing, selling products or services." These two items mentioned the value of statistics in determining the price of a product. In contrast, the experimental group had 13 items related to this theme. In addition to determining the price of a product, the experimental group indicated that statistics could be used to understand the market and the preference of target customers.

Third, "comparison" was the most frequently mentioned word among items related to the theme "technical work" for both groups. The control group participants indicated that statistics could be used to compare different materials, designs, solutions, and components in experiments to find the best one (e.g., "testing out several similar designs/models to see which performs well"). The experimental group mentioned two additional benefits of statistics related to comparison:

1. the use of statistics to help engineers make choices based on objective standards rather than a comparison of options (e.g., "trends in weather patterns can help humanitarian engineers decide on resources and locations for buildings"), and
2. the use of statistics to make positive and negative judgments of a single element (e.g., "when creating an object and testing it out, we could use statistics to identify if it works out good or not").

In addition, items in both groups related to the theme "technical work" include the use of statistics to analyze engineering systems (e.g., machines). The control group focused on the systems themselves, such as the use of statistics to:

1. analyze the performance or effectiveness of a system (e.g., "as a mechanical engineer, you would use statistics to study your test results when testing the performance of a machine you are working on"),
2. calculate the values of variables in experiments or tests and understand the nature of these values (e.g., "understanding the nature of errors [……] is important to create software that will operate machinery. The software must not break or allow the hardware to break from errors that can be calculated/expected"),
3. analyze how a product is used (e.g., "analyzing how a sensor is used"), and
4. perform mathematical modeling (e.g., "creating a mathematical model for how a system might act").

In contrast, the experimental group mentioned the methods for understanding an engineering system as well as continuously improving products and increasing their value:

1. statistics can make machines intelligent (e.g., "in designing learning algorithms so robots can draw conclusions from past data" and "a car adjusts power and torque by changing gears based on how fast it is going and whether it's going up or down a hill"),

2. statistics can increase the precision of calculation, data analysis, and making machines (e.g., “in the satellite and GPS industry—when making a system as accurate as possible”),
3. statistics can be used by engineers to get user feedback data to improve products (e.g., “feedback data from user so that we know what to improve or to design”), and
4. statistics can enable engineers to find mistakes and solve problems (e.g., “statistics allows engineers to solve problems based on significant data analysis”).

Overall, a comparison of examples related to the engineering field revealed that the experimental group’s content was richer than that of the control group. Specifically, students in the experimental group had more knowledge than their control group peers about using statistics in marketing, decision-making, and engineering system improvement.

4.2. Personal Identification Level

4.2.1. Frequency of First-Person Pronouns

First-person singular pronouns (i.e., I, me, my) were used more frequently in control group items than in experimental group items. In contrast, first-person plural pronouns (i.e., we, us, our) occurred more frequently in experimental group items than in control group items. Table 5 shows the detailed frequency statistics of items using personal pronouns.

Table 5. Statistical comparison of items using first-person pronouns.

Personal pronouns	Number of items: Control (%)	Experimental (%)
First-person singular (total)	8* (9.6)	9 (5.7)
I	5 (6.0)	5 (3.1)
me	3 (3.6)	0 (0.0)
my	2 (2.4)	4 (2.5)
First-person plural (total)	1 (1.2)	17** (10.7)
we	1 (1.2)	9 (5.7)
us	0 (0.0)	9 (5.7)
our	0 (0.0)	1 (0.6)

Note. *: two examples included both “I” and “my.”
**: two examples included both “we” and “us.”

The use of first-person singular pronouns (i.e., “I”) indicated that the respondent was the only referent for the corresponding item. For example, one participant claimed, “I can graph and display when results from an experiment are out of control using control charts.” First-person singular pronouns could also be used to present the respondent’s individual behavioral characteristics or preferences (e.g., “I would use statistics when choosing different materials to build vehicle parts”). In this example, the choice of materials is the respondent’s behavior and is not relevant to readers.

First-person plural pronouns (i.e., “we”) can be used for either inclusive or exclusive references (Kuo 1999; Yeo and Ting 2014). An inclusive first-person plural pronoun includes both the respondent and the reader, whereas an exclusive first-person plural pronoun does not include the reader. The control group had one item using first-person plural pronouns (“we could use it to determine on average what material is better to use”). In this item, the word “we” referred to all people in the engineering discipline.

In contrast, the experimental group had 17 items that used first-person plural pronouns, and these items were categorized into three referents. Three items exclusively referred to the members of the respondent’s project team (e.g., “using statistics to identify if a hypothesis created about some lab our engineering team has created is correct or not”). This usage showed the respondent’s perception of their project team as an organic whole, and the impact of statistics was related to the work created by the team. Another two items exclusively referred to the engineering discipline the respondents belonged to (e.g., “statistics is relevant to electrical engineers because it allows us to harvest information on products and shows us what needs improvement/how reliable our products are”). The remaining 12 items were categorized as inclusive because the semantic references were broadly inclusive of the engineering field (e.g., “when creating an object and testing it out, we could use statistics to identify if it works out good or not”). This usage implied that the respondent considered the reader as a partner, and the referent of the first-person plural pronouns was the engineering field.

In summary, students in the control group were inclined to consider themselves as individuals when connecting statistics to their experience, discipline, or career. In contrast, students in the experimental group were more likely to discuss the relevance of statistics from a perspective of themselves as members of the engineering community (e.g., a member of an engineering team and a partner of engineers).

4.2.2. Semantic References and Discourse Functions

Table 6 presents the statistics of the semantic references of first-person pronouns and their corresponding discourse functions. There are three meaningful differences between the control and experimental groups. First, when “stating statistics-related skills that the respondent or the community has,” control group respondents more frequently used singular pronouns than plural pronouns, whereas experimental group respondents used a nearly equal frequency of singular pronouns and plural pronouns.

Second, when “claiming the benefits that statistics brings to the respondent or the community to complete a task,” control group respondents only used first-person singular pronouns, whereas experimental group respondents only used first-person plural pronouns. Third, only one item in the control group used first-person pronouns to “establish a link between statistics and writers’ projects, disciplines, or future career,” whereas 10 items in the experimental group did so. The only item in the control group that used first-person pronouns in this way was “My career may require that I create a program to calculate the probability of certain event.” Typical items in the experimental group were “Statistics is relevant to electrical engineers because it allows us to harvest information on product and shows us what needs improvement/how reliable our products are” and “Clean water initiatives are crucial in the world right now. We need statistics for trials and experimentation.”

The first two differences identified in this subsection strengthen the theory that students in the control group were more likely to regard themselves as individuals when thinking of the relevance of statistics, whereas students in the experimental group were more likely to consider themselves as members of engineering communities. The third difference identified in

Table 6. Statistics of semantic references of first-person pronouns.

	Discourse functions	First-person singular		First-person plural	
		Control	Experimental	Control	Experimental
1	State statistics-related skills that the respondent or the community has.	4	4	1	5
2	Claim the benefits that statistics brings to the respondent or the community to complete a task.	3	0	0	7
3	Establish links between statistics and respondents' projects, disciplines, or future careers.	1	5	0	5

this subsection demonstrated that students in the experimental group were more likely to connect statistics with themselves from a broader scope than the control group, which implied a farther transfer of learning.

5. Discussion

The aim of this study is to explore the potential of PjBL in promoting students' perceptions of statistics relevance in an engineering statistics course. Four mini-projects connecting statistics to students' experiences and future careers were designed and implemented during a 16-week course. Students' responses to the survey question, "Provide at least three examples of how statistics is relevant to your engineering discipline, your anticipated career, and/or engineers, in general" at the end of the semester were analyzed and compared with the responses of students in a traditional statistics course. This study begins to fill a research gap by exploring students' perceptions of statistics relevance after a PjBL intervention. Additional studies in this area may help researchers and educators better understand the potential of PjBL in statistics course instruction. This section will discuss the meaning of the analysis results regarding personal usefulness and personal identification levels.

5.1. *Usefulness of Statistics*

The content from the experimental group examples is more diverse than that of the control group. Students in the experimental group connected statistics to marketing, decision-making, and engineering systems' improvement, none of which was found in the control group's responses. The current study findings are aligned with those of Daniel and Braasch (2013) in which students exposed to a PjBL exercise tended to propose more real-world uses of statistics and fewer "no application" responses than students in control groups. These differences imply that PjBL interventions have the potential to help students explore applications of statistics in engineering. Such exploration can empower students to move beyond the knowledge instructed in the classroom to draw more connections between statistics and their lives, majors, and future careers.

5.2. *Engineering as Personal Identification*

This is one of the first studies to use a linguistic method to analyze individuals' perceptions. The linguistic analytical results indicate that students in the experimental group were more likely than those in the control group to talk about the connection between statistics and their disciplines but not themselves. This contrast implies that students involved in the PjBL activities were more inclined to regard themselves as a part of the engineering community. This result is aligned with previous findings that engineering-related experiences have the potential to develop a sense of engineering belonging and increase engineering identity for engineering undergraduate students (Mann et al. 2009; Meyers et al. 2012; Rohde et al. 2019; Social and Premium 2011). This finding can also be explained through the community of practice theory (Wenger 1999), which proposes that engagement, imagination, and alignment are three critical modes of belonging. Students' engagement in activities in which they can work with peers with similar interests may help them form a perception of belonging. The use of PjBL interventions to develop students' professional identity has been reported in the existing literature with positive findings (Du 2019; Langer-Osuna 2015; Tsybulsky and Muchnik-Rozanov 2019). Still, it is novel to find that a PjBL intervention has a positive effect on students' perceptions of belonging in a statistics course because prior research has only assessed students' motivation and learning gains.

6. Limitations

We have identified five limitations to this study's implementation. First, the control class and experimental class had different instruction formats (online versus in-person learning). The lecture content was the same; however, the instructional format may have affected participants' perceptions and other learning outcomes. In addition, participants self-selected the class that they engaged in. External factors may have affected participants' class selection, and participants' learning competencies and/or course interest may have differed between the two classes. Third, all participants in this study were students in the same engineering college at a university. Participants may have communicated their experiences in the engineering statistics course with others in the same class or the parallel class and such communication may have influenced the survey results. Fourth, although the two faculty members have a similar professional background, there are still possible differences in their instructional style and preference, which can also be an important confounding variable. Finally, the study compared participants from two classes during a one-semester course. The small sample size may have affected the analytical results.

7. Conclusion and Future Work

Understanding statistics is essential for engineers who depend upon statistical analyses for various engineering tasks (Montgomery, Runger, and Hubele 2010). Unfortunately, statistics courses are often cited as difficult and ineffective and a source of stress and anxiety for students (Neumann, Hood, and Neumann 2013; Rivera, Marazzi, and Torres-Saavedra 2019; Wathen and

Rhew 2019). There is a critical need for restructuring statistics courses to be more effective, particularly for engineering students. The authors of this article explored the impact of a PjBL intervention on students' perceptions of engineering and statistics in engineering. The purpose of the intervention was to help students understand the connection between statistics and their academic major, lives, and future careers. The intervention consisted of four mini-projects that were embedded in a one-semester engineering statistics course. Students' survey responses after the intervention indicated that the students in the experimental group seemed to have a stronger understanding of the usefulness of statistics in engineering than students in the control group. The PjBL intervention also seems to have enhanced the experimental group students' perception of belonging to the engineering community. It is surprising that no meaningful difference was found between the control group and the experimental group in the hours participants spent preparing for and participating in the course (control group: mean = 4.6 hours, SD = 3.0; experimental group: mean = 4.8 hours, SD = 1.9). Thus, the intervention does not seem to increase students' workload in the statistics course.

In summary, the use of a PjBL intervention in an engineering statistics course has the potential to enhance students' perception of statistics relevance. The overall benefits of PjBL course instruction seem to be greater than the potential drawbacks. The confounding of instructor effect and treatment effect are not trivial aspects of the design that may have influenced the students' survey responses, and ultimately, the research findings. Although limitations exist in the experimental design and implementation, the study findings demonstrate the potential of such interventions. In the future, we plan to continue to explore PjBL in engineering statistics education through studies with more rigorous experimental control and broader participant groups. We encourage other educators and researchers to design their own experiments as well as adopt a PjBL model in their engineering statistics course instruction.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Data Accessibility Statement

Data is available upon request from the authors.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Supplementary Materials

Appendix A is the course's schedule. Appendix B is the course's competency-based assessment.

ORCID

Wen Huang http://orcid.org/0000-0002-9155-0547

References

Andersson, C., and Kroisandt, G. (2021), "Work in Progress: First Experiences with a Flipped Online Statistics Classroom for Engineering Students," in *2021 International e-Engineering Education Services Conference (e-Engineering)*, IEEE, 103–106. https://doi.org/10.1109/e-engineering47629.2021.9470682.

Cetinkaya-Rundel, M. I., N, E., Dogucu, M., and Rummerfield, W. (2022), "The 5Ws and 1H of Term Projects in the Introductory Data Science Classroom," *Statistics Education Research Journal*, 21, 4–4. https://doi.org/10.52041/serj.v21i2.37.

Cohen, G. (2014), "The Power of the First-Person Perspective," available at *http://meetcontent.com/blog/power-first-person-perspective/*.

Daniel, F., and Braasch, J. L. G. (2013), "Application Exercises Improve Transfer of Satistical Knowledge in Real-World Situations," *Teaching of Psychology*, 40, 200–207. https://doi.org/10.1177/0098628313487462.

Delucchi, M. (2007), "Assessing the Impact of Group Projects on Examination Performance in Social Statistics," *Teaching in Higher Education*, 12, 447–460. https://doi.org/10.1080/13562510701415383.

Du, M. (2019), "An Empirical Study of Learners Agency and Identity in Project-Based Learning," in *2019 5th International Conference on Humanities and Social Science Research (ICHSSR 2019)*, 655–659, Atlantis Press.

Du, X., and Han, J. (2016), "A Literature Review on the Definition and Process of Project-Based Learning and Other Relative Studies," *Creative Education*, 07, 1079–1083. https://doi.org/10.4236/ce.2016.77112.

Erdil, N. O. (2021), "*Fostering Entrepreneurial Mindset in an Engineering Statistics Course*," in ASEE Virtual Annual Conference.

Farrell, F., and Carr, M. (2019), "The Effect of Using a Project-Based-Learning (PBL) Approach to Improve Engineering Students' Understanding of Statistics," *Teaching Mathematics and Its Applications: An International Journal of the IMA*, 38, 135–145.

Halvorsen, K. T. (2010), "Formulating Statistical Questions and Implementing Statistics Projects in an Introductory Applied Statistics Course," in *Proceedings of the 8th International Conference on Teaching Statistics*, 1–5.

Helgevold, N., and Moen, V. (2015), "The Use of Flipped Classrooms to Stimulate Students' Participation in an Academic Course in Initial Teacher Education," *Nordic Journal of Digital Literacy*, 2015, 29–42. https://doi.org/10.1177/1049732305276687.

Kokotsaki, D., Menzies, V., and Wiggins, A. (2016), "Project-Based Learning: A Review of the Literature," *Improving Schools*, 19, 267–277.

Kolmos, A., and de Graaff, E. (2014), "Problem-Based and Project-Based Learning in Engineering Education: Merging Models," in *Cambridge Handbook of Engineering Education Research*, eds. A. Johri and B. M. Olds, New York, NY: Cambridge University Press, 141–160.

Kuo, C. (1999), "The Use of Personal Pronouns: Role Relationships in Scientific Journal Articles," *English for Specific Purposes*, 18, 121–138.

Langer-Osuna, J. M. (2015), "From Getting 'Fired' to Becoming a Collaborator: A Case of the Coconstruction of Identity and Engagement in a Project-Based Mathematics Classroom," *Journal of the Learning Sciences*, 24, 53–92.

Larsen, K., Saad, H., Hossain, A., Bae, H., and Amin, A. (2018), "Optimizing the Curriculum in an Engineering Statistics Course with Realistic Problems to Enhance Learning," in ASEE Zone IV Conference, Boulder, Colorado.

Mann, L., Howard, P., Nouwens, F., and Martin, F. (2009), "Influences on the Development of Students' Professional Identity as an Engineer," *2009 Research in Engineering Education Symposium, Rees, 2009*, 1–6.

Martonosi, S. E., and Williams, T. D. (2016), "A Survey of Statistical Capstone Projects," *Journal of Statistics Education*, 24, 127–135. https://doi.org/10.1080/10691898.2016.1257927.

Meyers, K. L., Ohland, M. W., Pawley, A. L., Silliman, S. E., and Smith, K. A. (2012), "Factors Relating to Engineering Identity," *Global Journal of Engineering Education*, 14, 119–131.

Montgomery, D. C., Runger, G. C., and Hubele, N. F. (2010), *Engineering Statistics*, Hoboken, NJ: John Wiley & Sons.

Morelock, J. R. (2017), "A Systematic Literature Review of Engineering Identity: Definitions, Factors, and Interventions Affecting Development, and Means of Measurement," *European Journal of Engineering Education*, 42, 1240–1262. https://doi.org/10.1080/03043797.2017.1287664.

Neumann, D. L., Hood, M., and Neumann, M. M. (2013), "Using Real-Life Data when Teaching Statistics: Student Perceptions of this Strategy in an

Introductory Statistics Course," *Statistics Education Research Journal*, 12, 59–70.

Prince, M. J., and Felder, R. M. (2006), "Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases," *Journal of Engineering Education*, 95, 123–138. https://doi.org/10.1002/j.2168-9830.2006.tb00884.x.

Priniski, S. J., Hecht, C. A., and Harackiewicz, J. M. (2018), "Making Learning Personally Meaningful: A New Framework for Relevance Research," *Journal of Experimental Education*, 86, 11–29. https://doi.org/10.1080/00220973.2017.1380589.

Ravitz, J. (2010), "Beyond Changing Culture in Small High Schools: Reform Models and Changing Instruction with Project-Based Learning," *Peabody Journal of Education*, 85, 290–312. https://doi.org/10.1080/0161956X.2010.491432.

Rivera, R., Marazzi, M., and Torres-Saavedra, P. A. (2019), "Incorporating Open Data into Introductory Courses in Statistics," *Journal of Statistics Education*, 27, 198–207. https://doi.org/10.1080/10691898.2019.1669506.

Rohde, J., Musselman, L., Benedict, B., Verdín, D., Godwin, A., Kirn, A., Benson, L., and Potvin, G. (2019), "Design Experiences, Engineering Identity, and Belongingness in Early Career Electrical and Computer Engineering Students," *IEEE Transactions on Education*, 62, 165–172. https://doi.org/10.1109/TE.2019.2913356.

SAS (2021), "JMP." Cary, NC.

Savin-Baden, M. (2007), "Challenging Models and Perspectives of Problem-Based Learning," in *Management of Change*, Rotterdam, The Netherlands: Brill Sense, 9–29. https://doi.org/10.1007/978-0-387-09829-6.

Social and Premium. (2011), "Constructing Professional Portfolios: Sense-Making and Professional Identity Development for Engineering Undergraduates," *Journal of Engineering Education*, 100, 9–29.

Songsore, E., and White, B., J. G. (2018), "Students' Perceptions of the Future Relevance of Statistics After Completing an Online Introductory Statistics Course," *Statistics Education Research Journal*, 17, 120–140.

Spence, D. J., Bailey, B., and Sharp, J. L. (2017), "The Impact of Student-Directed Projects in Introductory Statistics," *Statistics Education Research Journal*, 16, 240–261. https://doi.org/10.52041/serj.v16i1.230.

Tawfik, A. A., and Lilly, C. (2015), "Using a Flipped Classroom Approach to Support Problem-Based Learning," *Technology, Knowledge and Learning*, 20, 299–315. https://doi.org/10.1007/s10758-015-9262-8.

Tonso, K. L. (2014), "Engineering Identity," in *Cambridge Handbook of Engineering Education Research*, eds. A. Johri and B. M. Olds, New York, NY: Cambridge University Press, 267–282.

Trevelyan, J. (2007), "Technical Coordination in Engineering Practice," *Journal of Engineering Education*, 96, 191–204. https://doi.org/10.1002/j.2168-9830.2007.tb00929.x.

Tsybulsky, D., and Muchnik-Rozanov, Y. (2019), "The Development of Student-Teachers' Professional Identity while Team-Teaching Science Classes Using a Project-Based Learning Approach: A Multi-Level Analysis," *Teaching and Teacher Education*, 79, 48–59.

Vidic, A. D. (2011), "Impact of Problem-Based Statistics Course in Engineering on Students' Problem-Solving Skills," *International Journal of Engineering Education*, 27, 885–896.

Wales, K. (1996), "You and Me, Them and Us: The Politics of Pronouns," in *Personal Pronouns in Present-Day English*, New York City, NY: The Press Syndicate of the University of Cambridge, 50–77.

Wathen, S., and Rhew, N. D. (2019), "Using Real-Life Major League Baseball Data in an Introductory Statistics Course," *Decision Sciences Journal of Innovative Education*, 17, 194–213. https://doi.org/10.1111/dsji.12185.

Wenger, E. (1999), *Communities of Practice: Learning, Meaning, and Identity*. New York, NY: Cambridge University Press.

Yeo, J., and Ting, S. (2014), "English for Specific Purposes Personal Pronouns for Student Engagement in Arts and Science Lecture Introductions," *English for Specific Purposes*, 34, 26–37. https://doi.org/10.1016/j.esp.2013.11.001.